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SPIN-TUNNEL INVESTIGATION OF A 1/20-SCALE MODEL OF A STRAIGHT-WING, TWIN-BOOM, COUNTER-INSURGENCY AIRPLANE

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SUMMARY

An investigation has been made in the Langley spin tunnel to determine the erect and inverted spin and recovery characteristics of a 1/20-scale dynamic model of a straight-wing, twin-boom, counter-insurgency airplane. Tests were made for the normal loading with the center of gravity at 28-percent mean aerodynamic chord and for a forward and rearward position at 17-percent and 30-percent mean aerodynamic chord, respectively. The landing configuration for the normal loading was also investigated. Additional tests were made to determine the effect of the sponsons, the external wing-tip-mounted missiles, external rocket pods, and an external gun pod. The use of rockets as an emergency recovery device was also investigated.

The test results indicate that the airplane will spin in the erect attitude for all loading conditions and will spin inverted only for aileron-with control settings. The optimum control technique for recovery from all spins is movement of the rudder to against the spin followed about one-half turn later by neutralization of the longitudinal and lateral controls. Stores mounted on the wings and sponsons will have no appreciable effect on the spin and recovery characteristics. For spins in the landing configuration, the flaps and landing gear should be retracted and then followed by the optimum control technique for recovery. Satisfactory recoveries from spins during an emergency can be obtained by the use of rockets that produce an antispin yawing moment (about the Z body axis) of at least 18 670 foot-pounds (25 313 m-N) for at least 4.5 seconds.

INTRODUCTION

The subject investigation was made to determine the spin and recovery characteristics of a 1/20-scale model of a straight-wing, twin-boom, counter-insurgency airplane.

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*The information presented herein was previously made available to the U.S. Naval Air Systems Command.

SYMBOLS

b	wing span, feet (meters)
$\bar{c}$	mean aerodynamic chord, feet (meters)
I_X, I_Y, I_Z	moments of inertia about X, Y, and Z body axes, respectively, slug-feet^2 (kilogram-meters^2)
$\frac{I_X - I_Y}{mb^2}$	inertia yawing-moment parameter
$\frac{I_Y - I_Z}{mb^2}$	inertia rolling-moment parameter
$\frac{I_Z - I_X}{mb^2}$	inertia pitching-moment parameter
m	mass of airplane, slugs (kilograms)
S	wing area, square feet (meters^2)
V	full-scale true rate of descent, feet/second (meters/second)
x	distance of center of gravity rearward of leading edge of mean aerodynamic chord, feet (meters)
z	distance between center of gravity and fuselage reference line (positive when center of gravity is below line), feet (meters)
α	angle between fuselage reference line and vertical (approximately equal to absolute value of angle of attack at plane of symmetry), degrees
μ	relative density of airplane, $\frac{m}{\rho S b}$
ρ	air density, slug/cubic foot (kilogram/meter^3)
ϕ	angle between span axis and horizontal, degrees
Ω	full-scale angular velocity about spin axis, revolutions/second

TESTS

The tests were run in the Langley spin tunnel which is described in reference 1. The test technique is described in detail in reference 1, and a brief summary of the technique is given in the appendix of the present report for the convenience of the reader. The appendix also indicates the precision of measurement of the characteristics of the spin.

The erect and inverted spin and recovery characteristics were determined for a range of center-of-gravity locations from 17 percent to 30 percent of the mean aerodynamic chord. Loadings with external stores including some asymmetric loading conditions were investigated. The investigation also included the landing configuration. Also tests were conducted with small rockets mounted on the wing tips to determine the yawing moment required for an emergency spin recovery.

MODEL

A 1/20-scale model of the airplane was prepared for testing by the Langley Research Center. A three-view drawing of the model is shown in figure 1, and a photograph of the model is shown in figure 2. The dimensional characteristics of the airplane are presented in table I.

The model was ballasted to obtain dynamic similarity to the airplane at an altitude of 20 000 feet (6096 meters) (ρ = 0.001267 slug/ft^3 or 0.65 kg/m^3). The mass characteristics and mass parameters for typical loadings possible on the airplane and for the corresponding loading conditions tested on the model are presented in table II.

Because it is impracticable to ballast models exactly and because of inadvertent damage to models during tests, the measured weight and mass distribution of the model varied from the true scaled-down values within the following limits:

Weight, percent . . . . 4 low to 1 high
Center-of-gravity location, percent $\bar{c}$ . . . . 0 to 2 rearward
Moments of inertia:
- I_X, percent . . . . 4 low to 1 high
- I_Y, percent . . . . 0 low to 7 high
- I_Z, percent . . . . 3 high to 5 high

A remote-control mechanism was installed in the model to actuate the control surfaces and rockets for the recovery attempts. Sufficient torque was exerted on the controls to reverse them fully and rapidly for the recovery attempts. The airplane was equipped with spoilers but they were not used on the model because it has been found in the past that upper surface spoilers have no effect on the spin or recovery from erect spins.

The normal maximum control deflections of the airplane used on the model during the tests (measured perpendicular to the hinge lines) were:

Rudder, deg	25 right, 25 left
Elevator, deg	35 up, 15 down
Aileron, deg	25 up, 25 down
Flaps:	
Inboard, deg	25 down
Outboard, deg	25 down

RESULTS AND DISCUSSION

The results of the model spin tests are presented in charts 1 to 9 and in tables III and IV. The model data are presented in terms of full-scale values for the airplane at an altitude of 20 000 feet (6096 meters) except as indicated. Inasmuch as the results for right and left spins were generally similar, the data are presented arbitrarily in terms of right spins. The model in the clean configuration has the sponsons on (see fig. 1). Propellers were not simulated on the model, but on the basis of spin-tunnel experience, the results presented are considered to be generally applicable for the airplane spinning either to the right or to the left with idling propellers. Because the two propellers of the airplane rotate in opposite directions, there would be virtually no gyroscopic effects on the spinning airplane.

In general, the tests showed that the model had two erect spin modes, one a fairly steep fast-rotating spin with angles of attack of about 20° to 30°, and the other a flatter and slower rotating spin with angles of attack in the order of 35° to 50°. The model could change from one of these modes to the other and could sometimes alternate between the two modes so fast that it was considered to be oscillatory. For the inverted spins, the tests showed that the model would spin very steep with high rotational rates or would not spin, depending on the control settings.

Satisfactory recoveries could be obtained from any of the spin modes in either the erect or inverted attitudes by use of the optimum control technique which is reversing the rudder to full against the spin followed about one-half turn later by neutralizing the lateral and longitudinal controls to prevent the model from entering a spin in the opposite direction.

Erect Spins

On the charts, results for elevator up (stick back) are presented at the top of the chart and results for elevator down (stick forward), at the bottom of the chart; results for ailerons with the spin (stick right in a right spin) are presented on the right side of the chart and results for ailerons against (stick left), on the left side of the chart.

Normal loading.- The results of the erect spin tests for the normal loading (loading 9, in table II) with a center-of-gravity location of $0.28\bar{c}$ are presented in chart 1. The results indicate that the spins are fast and steep. For the normal spin control settings, elevator full up and ailerons neutral, the period of the spin was about 2 seconds per turn at an angle of attack of approximately 25°. Any variation of the elevator setting from full to neutral resulted in a faster and steeper spin. Any variation of the ailerons from neutral to against the spin resulted in a slower and slightly flatter spin. The data presented indicate that for all control combinations tested, satisfactory recoveries were obtained by reversal of the rudder to full against the spin. The recoveries were rapid in all cases and the post-recovery motion was either a dive or a glide. The gliding motion was usually the result of the elevator being up. Recoveries attempted by neutralizing the rudder indicated that neutralizing the rudder will not produce satisfactory recoveries.

Effect of varying center-of-gravity location.- The results of the erect-spin tests with the forward center-of-gravity location ($0.17\bar{c}$, loading 8, in table II) and the rearward center-of-gravity location ($0.30\bar{c}$, loading 6, in table II) for the normal loading are presented in charts 2 and 3, respectively. The results in chart 2 are presented for an altitude of 25 000 feet (7620 meters) instead of 20 000 feet (6096 meters). The higher altitude was necessary in order to maintain the inertia yawing-moment parameters $\frac{I_X - I_Y}{mb^2}$ as near as possible to the value for the loadings in charts 1 and 3. The results for both center-of-gravity locations are, in general, similar to those for the normal loading center-of-gravity location ($0.28\bar{c}$) in chart 1. The highest spin rates were observed at the forward center-of-gravity location. In both cases, however, satisfactory recoveries could be obtained from any spin by reversing the rudder to full against the spin.

Effect of flaps.- The results of tests with the normal loading for the landing configuration (loading 10, in table II) are presented in chart 4. The tests were conducted with the flaps 25° down and the landing gear retracted. (Past experience has shown that the extended landing gear has no effect on the spin or recovery characteristics.) The spins on the model for the landing configuration, in general, were rotating faster and steeper than corresponding spins with flaps up, and the recoveries were satisfactory by rudder reversal.

Effect of sponsons.- The results of the erect-spin tests with the normal loading (loading 9 in table II) and with the sponsons removed are shown in chart 5. A comparison of charts 1 and 5 indicates that the sponsons had no significant effect on the spin or spin-recovery characteristics with the normal loading. Similar comparison of results of other tests, for which data are not presented, indicates that the sponsons had no significant effect on the spin or spin-recovery characteristics within the range of center-of-gravity locations investigated.

Effect of wing-tip-mounted missiles.- Tests were conducted to determine the effect of wing-tip-mounted missiles (loading 11, table II) and the results are presented in chart 6. Wing-tip-mounted missiles changed the inertia yawing-moment parameter from negative to positive. The results also indicated that spins occurred only when the elevator was up. The period of the spin varied between 2 and 3 seconds per turn, and the angle of attack varied between approximately 25° and 50°. Satisfactory recoveries from all spins were obtained by reversal of the rudder to full against the spin.

Past experience has shown that the spin and spin-recovery characteristics of an airplane can appreciably change for loadings where the inertia yawing-moment parameter is near zero. Therefore, tests were also conducted for this model where the inertia yawing-moment parameter was near zero (loading 12, in table II). The results of these tests are presented in chart 7. The results are similar to those discussed above in that spins occurred only when the elevator was up. However, the results do show that the spins were not as oscillatory and the angle of attack was fairly constant during the spins. Satisfactory recoveries were obtained from all spins by reversing the rudder to full against the spin.

Effect of four external rocket pods.- The results of tests conducted to determine the effect of four external rocket pods (loading 13, in table II) are presented in chart 8. The rocket pods are shown in figure 2(b). These results are very similar to those presented in chart 3 which are for the same loading without the external stores and indicate that the rocket pods had no significant effect on the spin or spin recovery characteristics.

Effect of external gun pod.- The results of tests conducted to determine the effect of a center gun pod mounted below the fuselage (loading 13, in table II) are presented in chart 9. The center gun pod is shown in figure 1. The results are generally similar to the results with the four external rocket pods (chart 8) and for the clean condition (chart 1) for the normal control setting (ailerons neutral and elevator full up). However, two types of spins were obtained at other control settings. Some of the recoveries were slow for the condition where the ailerons were full against and the elevators were neutral or full-down. For the criterion spin, however, the recoveries were satisfactory by reversing the rudder to against the spin.

Aerodynamic effect of external stores.- Tests were made on the model with a positive inertia yawing-moment parameter (loading 11, table II) to investigate possible aerodynamic effects of external store combinations. The following combinations were tested:

(1) Gun pod on, sidewinder missiles on

(2) Gun pod on, sidewinder missiles off

(3) Gun pod off, sidewinder missiles on

(4) Gun pod off, sidewinder missiles off.

The results (data not presented) indicated that the external stores had no appreciable aerodynamic effect on the spin and spin recovery characteristics. These results were similar to the positive loading results presented in chart 6.

Inverted Spins

The results of tests to determine the inverted-spin and recovery characteristics are presented in table III.

Several loadings were investigated and the results indicated that the spins were generally very steep with high rotational rates. Spins were obtained only when the ailerons were full with the spin. Satisfactory recoveries were obtained by reversing the rudder to full against the spin. After recovery the model would sometimes go into an aileron roll. The optimum control technique recommended for recovery from any inverted spin, therefore, is movement of the rudder to full against the spin and neutralizing the lateral and longitudinal controls.

Spin-Recovery Rocket Tests

The results of tests to evaluate the use of rockets for emergency recovery from demonstration spins are presented in table IV. The rockets were mounted on the wings at various distances from the fuselage center line to provide the moments indicated in the table. The rocket thrust and the number of seconds that the rocket fired are shown in the table. Airplane and model values under each heading pertaining to the rockets are given for comparison purposes. The airplane columns give the design values for the airplane and the model columns give the model values used for tests converted to full-scale values.

In previous investigations on other models to determine the size rocket needed for spin recovery, the direction of the rocket thrust with respect to the principal axes seemed to be important. The maximum inclination of the principal axes to the body axes on this airplane was about 8°. Therefore, tests were made with the rocket thrust set parallel to the body axes which resulted in a small rolling-moment component about the principal longitudinal axis (aileron-against effect), and when the rocket thrust was set at a 10° angle to the body axes, a pure yawing moment about the principal vertical axis resulted. The results of the test indicate that the tilt angle of the thrust vector had no appreciable effect on the recovery characteristics for this design.

Since the model spun oscillatory and oscillated between a flat and a steep spin mode, slow recoveries sometimes occurred when the recovery attempt was made as the spin was changing from one mode to the other. However, as indicated in table IV, the application of approximately 18 670 foot-pounds (25 313 m-N) of yawing moment for about 4.5 seconds (full scale) was adequate for satisfactory recoveries.

It is of importance to point out the significance of some of the unsatisfactory rocket recovery attempts. In several cases where no recovery was obtained, the total impulse was the same as that used for some of the satisfactory recovery attempts, but the applied yawing moment was less for the no recovery case. A small yawing moment may be unsatisfactory, therefore, even though it could be applied over a long period of time. In addition, these results have shown that a rocket with a short burning time cannot necessarily be compensated for by increasing the applied yawing moment. In many cases, the unsatisfactory recoveries resulted because the model did not stop rotating by the time the rocket stopped firing. It is necessary, therefore, that the rocket not only provide sufficient yawing moment for recovery, but also provide the moment for as long as the rotation is present.

Recommended Recovery Technique

On the basis of the results obtained in this investigation, the following recovery technique is recommended for the airplane for erect and inverted spins for all loading conditions: move rudder to full against the spin, and then move the elevators and ailerons to neutral about one-half turn later.

CONCLUSIONS

Based on the results of tests of a 1/20-scale model of a straight-wing, twin-boom, counter-insurgency airplane, the following conclusions regarding the spin and recovery characteristics of the airplane at 20 000 feet (6096 meters) are made:

1. The optimum recovery technique is movement of the rudder to full against the spin followed by movement of the elevators and ailerons to neutral about one-half turn later.

2. Recoveries from all erect and inverted spins for all loading conditions for both the clean and landing configuration will be satisfactory by using the optimum recovery technique.

3. The center-of-gravity location will have no appreciable effect on the spin and recoveries.

4. The sponsons will have no appreciable effect on the spin and the recovery characteristics.

5. The addition of stores, tanks, gun and rocket pods, and wing-tip missiles will have no appreciable effect on the spin and recovery characteristics.

6. A rocket mounted on the wing to give an antispin yawing moment of 18 670 foot-pounds (25 313 m-N) about the Z body axis for at least 4.5 seconds (full scale) will be satisfactory for emergency recoveries from any spins obtained.

Langley Research Center,
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APPENDIX

TEST METHODS AND PRECISION

Model Testing Technique

General descriptions of model testing techniques, methods of interpreting test results, and correlation between model and airplane results are presented in reference 1.

Spin-tunnel tests are usually performed to determine the spin and recovery characteristics of a model for the normal control configuration for spinning (elevator full up, lateral controls neutral, and rudder full with the spin) and for various other lateral control and elevator combinations including neutral and maximum settings of the surfaces. Recovery is generally attempted by rapid full reversal of the rudder, by rapid full reversal of both rudder and elevator, or by rapid full reversal of the rudder simultaneously with the movement of the ailerons to full with the spin. Tests are conducted for the various possible loading conditions of the airplane because the control manipulation required for recovery is generally dependent on the mass and dimensional characteristics of the model. (See ref. 1.) Tests are also performed to evaluate the possible adverse effects on recovery of small deviations from the normal control configuration for spinning. For these tests, the elevator is set at either full-up deflection or two-thirds of its full-up deflection, and the lateral controls are set at one-third of full deflection in the direction conducive to slower recoveries, which may be either against the spin (stick left in a right spin) or with the spin, depending primarily on the mass characteristics of the particular model. Recovery is attempted by rapidly reversing the rudder from full with the spin to only two-thirds against the spin, by simultaneous rudder reversal to two-thirds against the spin, and movement of the elevator to either neutral or two-thirds down, or by simultaneous rudder reversal to two-thirds against the spin and stick movement to two-thirds with the spin. This control configuration and manipulation is referred to as the "criterion spin," the particular control settings and manipulation used being dependent on the mass and dimensional characteristics of the model.

Turns for recovery are measured from the time the controls are moved to the time the spin rotation ceases. Recovery characteristics of a model are generally considered to be satisfactory if recovery attempted from the criterion spin in any of the manners previously described is accomplished within $2\frac{1}{4}$ turns. This value has been selected on the basis of full-scale-airplane spin-recovery data that are available for comparison with corresponding model test results.

For spins in which a model has a rate of descent in excess of that which can readily be obtained in the tunnel, the rate of descent is recorded as greater than the velocity at the time the model hit the safety net, for example, >300 feet per second, full scale. In such tests, the recoveries are attempted before the model reaches its final steeper attitude and while it is still descending in the tunnel. Such results are considered conservative; that is, recoveries are generally not as fast as when the model is in the final steeper attitude. For recovery attempts in which a model strikes the safety net while it was still in a spin, the recovery is recorded as greater than the number of turns from the time the controls were moved to the time the model struck the net, for example, >3. A >3-turn recovery, however, does not necessarily indicate an improvement over a >7-turn recovery. A recovery of 10 or more turns is indicated by ∞. When a model recovers without control movement (rudder held with the spin), the results are designated as "no spin."

For spin-recovery rocket tests, the minimum moment due to rocket thrust required to effect recovery within $2\frac{1}{4}$ turns from the criterion spin is determined. The rocket is fired for the recovery attempts by actuating the remote-control mechanism, and the rudder is held with the spin so that recovery is due to the rocket action alone.

Precision

Results determined in free-spinning tunnel tests are believed to be true values given by models within the following limits:

α, deg	±1
ϕ, deg	±1
V, percent	±5
Ω, percent	±2
Turns for recovery obtained from motion-picture records	±1/4
Turns for recovery obtained visually	±1/2

The preceding limits may be exceeded for certain spins in which the model is difficult to control in the tunnel because of the high rate of descent or because of the wandering or oscillatory nature of the spin.

The accuracy of measuring the weight and mass distribution of models is believed to be within the following limits:

Weight, percent	±1
Center-of-gravity location, percent $\bar{c}$	±1
Moments of inertia, percent	±5

Controls are set within an accuracy of $\pm 1^{\circ}$.

REFERENCE

1. Neihouse, Anshal I.; Klinar, Walter J.; and Scher, Stanley H.: Status of Spin Research for Recent Airplane Designs. NASA TR R-57, 1960. (Supersedes NACA RM L57F12.)

TABLE I.- DIMENSIONAL CHARACTERISTICS OF THE AIRPLANE

Overall length, ft (m)	39.19 (11.95)
Nacelle span (distance between the nacelle center lines), in. (cm)	163 (414)
Sponson dihedral angle, deg	0
Wing:	
Span, ft (m)	30 (9.14)
Area, ft^2 (m^2)	218 (20.25)
Mean aerodynamic chord, in. (cm)	87.25 (221.62)
Root chord, in. (cm)	87.25 (221.62)
Tip chord, in. (cm)	87.25 (221.62)
Taper ratio	1.0
Aspect ratio	4.13
Airfoil section	NACA 64_2A315 (Mod.)
Incidence relative to fuselage reference line, deg	3.0
Dihedral, deg	0
Sweep of 0.25-chord line, deg	0
Flap area (total), ft^2 (m^2)	34.17 (3.17)
Flap type	Double slotted
Flap chord, in. (cm)	24.8 (62.99)
Aileron area (total), ft^2 (m^2)	8.30 (0.77)
Aileron span, in. (cm)	34.13 (86.69)
Aileron chord, in. (cm)	17.45 (44.32)
Spoiler span (upper surface), in. (cm)	59.8 (151.89)
Spoiler location, percent wing chord	58.7
Horizontal tail:	
Span, in. (cm)	163 (414)
Area, ft^2 (m^2)	70.3 (6.53)
Chord, in. (cm)	62.2 (157.99)
Taper ratio	1.0
Aspect ratio	2.62
Airfoil section	NACA 64_1A412 (Mod.) (Inverted)
Incidence relative to fuselage reference line, deg	2.0
Sweep of 0.25-chord line, deg	0
Elevator area, ft^2 (m^2)	24.90 (2.31)
Elevator span, in. (cm)	163 (414)
Elevator chord, in. (cm)	22 (55.88)
Vertical tail:	
Span, in. (cm)	86 (218.44)
Area (each), ft^2 (m^2)	34.88 (3.24)
Chord, in. (cm)	58.4 (148.3)
Taper ratio	1.0
Aspect ratio	1.47
Airfoil section	NACA 64_1A012
Sweep of 0.25-chord line, deg	32
Rudder area (each), ft^2 (m^2)	11.55 (1.07)
Rudder span, in. (cm)	69.4 (176.3)
Rudder chord, in. (cm)	24 (60.96)

TABLE II.- *MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR TYPICAL LOADING OF THE AIRPLANE AND FOR THE LOADINGS TESTED ON THE 1/20-SCALE MODEL*

[Values given are full scale, and moments of inertia are given about the center of gravity]

Number	Loading	Weight, lb (N)	Center-of-gravity location		Relative density, μ		Moments of inertia, slug-ft^2 (kg-m^2)			Mass parameters		
			$x/\bar{c}$	$z/\bar{c}$	Sea level	Altitude 20 000 ft (6096 m)	I_X	I_Y	I_Z	$\frac{I_X - I_Y}{mb^2}$	$\frac{I_Y - I_Z}{mb^2}$	$\frac{I_Z - I_X}{mb^2}$
						Airplane values						
1	Configuration 1; armed reconnaissance mission take-off gross weight (gear down)	8027 (35 706)	0.267	-0.077	16.0	30.1	7 877 (10 680)	10 130 (13 734)	14 352 (19 458)	-100×10^{-4}	-188×10^{-4}	288×10^{-4}
2	Configuration 6; armed reconnaissance with stores on and 60-percent take-off fuel	7569 (33 668)	.271	-.097	15.1	28.4	7 277 (9 866)	9 982 (13 534)	14 389 (19 509)	-128	-208	336
3	Configuration 8; visual reconnaissance with 60-percent take-off fuel	6676 (29 696)	.234	-.200	13.3	25.0	6 844 (9 279)	9 575 (12 982)	14 469 (19 617)	-146	-263	409
4	Configuration 9; ferry mission with external tank on and 60-percent take-off fuel	7153 (31 818)	.280	-.202	14.3	26.8	6 868 (9 312)	9 490 (12 867)	14 493 (19 650)	-131	-250	381
5	Configuration 10; maximum close air support with stores and 60-percent take-off fuel	9624 (42 809)	.208	-.036	19.2	36.1	8 031 (10 888)	11 534 (15 638)	15 736 (21 335)	-130	-156	286
6	Configuration 11; four paratroop missions with 60-percent take-off fuel	7441 (33 099)	.305	-.160	14.9	27.9	6 653 (9 020)	9 758 (13 230)	14 498 (19 656)	-149	-228	377
7	Configuration 20; basic flight design gross weight. Most forward center of gravity	7569 (33 668)	.168	-.106	15.1	28.4	6 815 (9 240)	10 832 (14 686)	14 981 (20 311)	-190	-196	386
8	Configuration 22; maximum close air support mission. Most forward center-of-gravity limit, 5-percent fuel (gear up)	6773 (30 128)	.154	-.153	13.5	25.3	6 448 (8 742)	10 450 (14 168)	15 094 (20 464)	-211	-246	457
						Model values						
9	Configuration 11; with forward center of gravity (normal loading)	7444 (33 112)	0.278	-0.214	14.86	27.86	6 158 (8 349)	10 054 (13 631)	15 071 (20 433)	-187×10^{-4}	-241×10^{-4}	428×10^{-4}
8	Configuration 22; maximum close air support mission. Most forward center-of-gravity limit; 5-percent fuel (gear up)	6798 (30 239)	.170	-.213	13.57	[a]25.45	6 354 (8 615)	10 489 (14 221)	15 563 (21 100)	-218	-267	485
6	Configuration 11; four paratroop missions with 60-percent take-off fuel	7500 (33 362)	.303	-.208	15.00	28.11	6 374 (8 642)	10 200 (13 829)	14 984 (20 315)	-182	-228	410
10	Configuration 11; in landing configuration	7415 (32 983)	.275	-.192	14.79	27.74	6 603 (8 952)	10 103 (13 698)	15 017 (20 360)	-169	-237	406
11	Configuration 11; with wing tip mounted sidewinder missiles	8138 (36 199)	.299	-.233	16.27	30.52	13 629 (18 478)	10 974 (14 879)	22 715 (30 797)	117	-516	399
12	Configuration 11; with wing tip mounted sidewinder missiles	8158 (36 288)	.307	-.229	16.27	30.52	9 998 (13 555)	11 164 (15 136)	19 217 (26 054)	-51	-354	405
13	Configuration 11; with four external rocket pods on or center gun pod on	7400 (32 917)	.301	-.204	14.79	27.75	6 811 (9 234)	10 893 (14 769)	15 566 (21 104)	-197	-226	423

[a]Value at 25 000-ft (7620-m) altitude for this loading.

TABLE III. - INVERTED SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL

[Recovery attempted by full rudder reversal unless otherwise noted. Recovery attempted from the developed spin data presented for rudder-full-with spin.]

Spin	Loading (table II)	Loading			Control setting for spin		Spin condition				Turns for recovery
		$\frac{I_X - I_Y}{mb^2}$	$x/\bar{c}$	Configuration	Aileron	Elevator	V, fps (m/s)	α, deg	ϕ, deg (a)	Ω, rps	
1	9	-187×10^4	0.278	Sponsons on	25° with	6° down	233 to 277 (71 to 84)	26 to 45	12U, 15D	0.42	$1\frac{1}{4}$, [b]1, [b]$1\frac{1}{4}$
2	9	-187	.278	Sponsons on	0°	6° down					No spin
3	6	-182	.303	Sponsons on	25° with	6° down	233 to 261 (71 to 80)	35	10U, 18D	.44	$\frac{3}{4}$, $>1\frac{1}{2}$
4	6	-182	.303	Sponsons on	0°	6° down					No spin
5	6	-182	.303	Sponsons off	25° with	6° down	241 to 277 (73 to 84)	38	6D	.44	$1\frac{1}{2}$, 2, >2
6	8	-218	.170	Sponsons on or sponsons off	25° with	6° down					No spin
7	8	-218	.170	Sponsons on or sponsons off	0°	6° down					No spin
8	11	117	.299	Configuration 11; side-winders on, sponsons on	0°	6° down					No spin
9	12	-51	.308	Configuration 11; side-winders on, sponsons on	25° with	6° down	333 (101)	25	5U, 2D	.58	----------
10	12	-51	.308	Configuration 11; side-winders on, sponsons on	0°	6° down					No spin
11	13	-197	.301	Four external rocket pods on, sponsons on	25° with	6° down	Steep spin				$>1\frac{1}{2}$
12	13	-197	.301	Four external rocket pods on, sponsons on	0°	6° down					No spin
13	13	-197	.301	Center gun pod on, sponsons on	25° with	6° down	Steep spin				

[a] U - Inner wing up; D - Inner wing down.

[b] Recovery by rudder movement to neutral.

TABLE IV.- ROCKET RECOVERY SPIN TESTS ON THE 1/20-SCALE MODEL OF THE AIRPLANE WITH ROCKETS SIMULATING YAWING MOMENT

[Model loading number 6, table II, Center of gravity = 30 percent $\bar{c}$; recovery attempted by firing rockets on wing; right erect spins; model values have been converted to full-scale values. Design values on the airplane are also listed.]

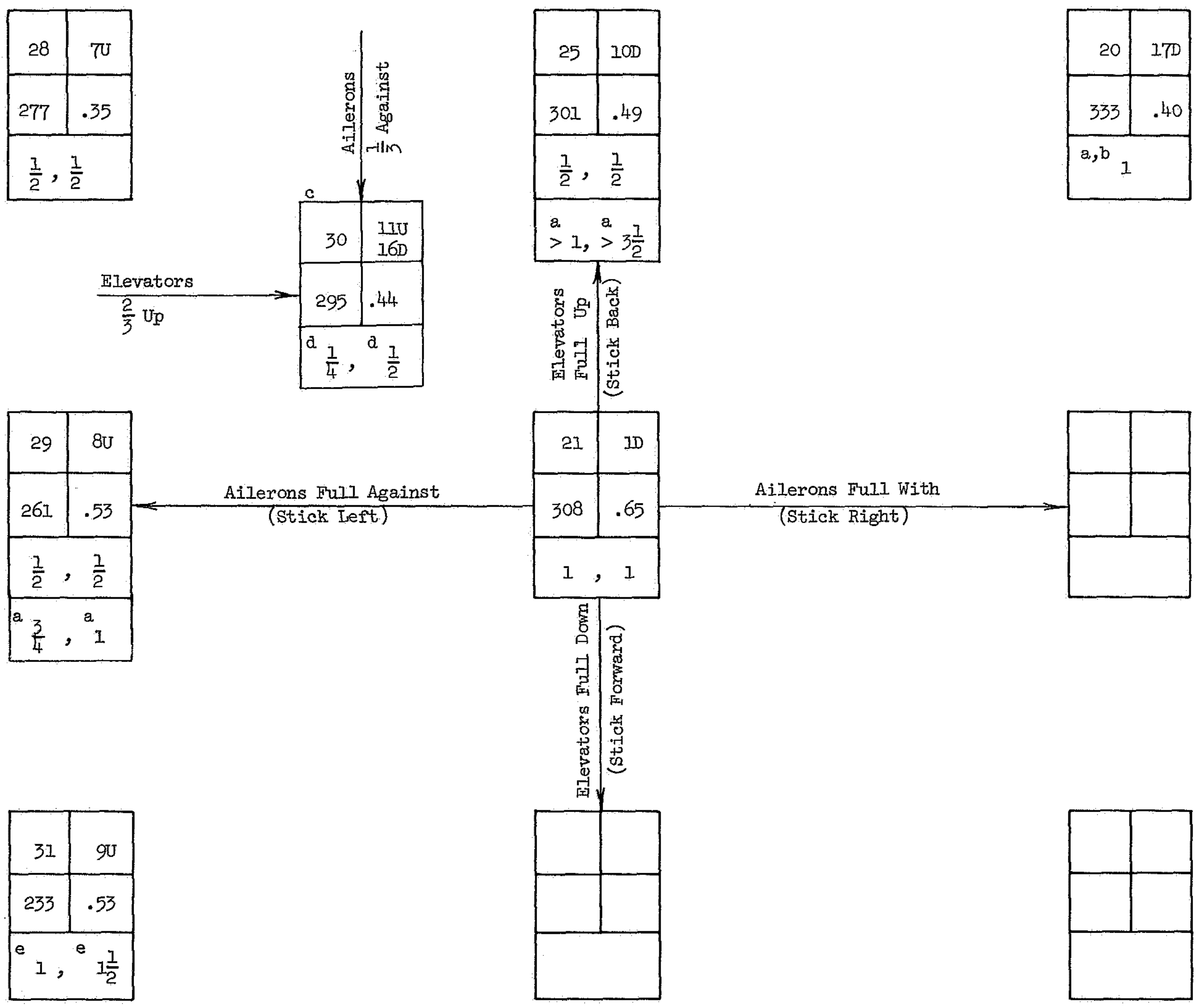
Spin	Control setting for spin			Rocket thrust, lb (N)		Location on Y-axis, in. (cm)		Firing time, sec		Moment applied, ft-lb (m-N)		Impulse, ft-lb-sec (m-N-sec)		Inclination of thrust line to fuselage reference line	Turns for recovery
	Rudder	Elevator	Aileron	Airplane	Model	Airplane	Model	Airplane	Model	Airplane	Model	Airplane	Model		
1	25° with	35° up	0°	1440 (6405)	800 (3559)	175 (445)	60 (152)	1.7	8.94	21 000 (28 472)	4 000 (5 423)	35 760 (48 483)	35 760 (48 483)	0°	$1, >4, >6\frac{1}{2}, >7$
2	25° with	23° up	8° against	1440 (6405)	800 (3559)	175 (445)	60 (152)	1.7	8.94	21 000 (28 472)	4 000 (5 423)	35 760 (48 483)	35 760 (48 483)	0°	$>3, >5, >6, \infty$
3	25° with	23° up	8° against	1440 (6405)	800 (3559)	175 (445)	120 (305)	1.7	4.47	21 000 (28 472)	8 000 (10 846)	35 760 (48 483)	35 760 (48 483)	0°	$>4, 1, 1\frac{1}{4}, 1, >3, 1\frac{1}{4}, 1\frac{1}{2}$
4	25° with	23° up	8° against	1440 (6405)	800 (3559)	175 (445)	140 (356)	1.7	4.47	21 000 (28 472)	9 334 (12 655)	35 760 (48 483)	41 721 (56 565)	0°	$1, 1\frac{1}{4}, >5, 1\frac{1}{4}, \frac{3}{4}, >1\frac{1}{2}$
5	25° with	0°	0°	1440 (6405)	800 (3559)	175 (445)	140 (356)	1.7	4.47	21 000 (28 472)	9 334 (12 655)	35 760 (48 483)	41 721 (56 565)	0°	$2\frac{1}{2}, 2, 2, 1\frac{1}{2}, 2\frac{1}{4}, 5$
6	25° with	0°	0°	1440 (6405)	800 (3559)	175 (445)	160 (406)	1.7	4.47	21 000 (28 472)	10 666 (14 461)	35 760 (48 483)	47 679 (64 668)	0°	$3, 2, 1\frac{1}{2}, 1\frac{3}{4}, 2\frac{1}{4}$
7	25° with	0°	5° against	1440 (6405)	800 (3559)	175 (445)	187 (475)	1.7	4.47	21 000 (28 472)	12 466 (16 901)	35 760 (48 483)	55 725 (75 552)	0°	$1, 1, 1\frac{1}{2}, 1, 1, 1, 1$
8	25° with	30° up	0°	1440 (6405)	800 (3559)	175 (445)	187 (475)	1.7	4.47	21 000 (28 472)	12 466 (16 901)	35 760 (48 483)	55 725 (75 552)	0°	$\frac{1}{2}, \infty, 1\frac{1}{2}, >5, \frac{1}{2}, >6, \infty$
9	25° with	30° up	0°	1440 (6405)	800 (3559)	175 (445)	187 (475)	1.7	4.47	21 000 (28 472)	12 466 (16 901)	35 760 (48 483)	55 725 (75 552)	5° up	$>5, 1, >5, 1\frac{1}{2}$
10	25° with	30° up	0°	1440 (6405)	800 (3559)	175 (445)	187 (475)	1.7	4.47	21 000 (28 472)	12 466 (16 901)	35 760 (48 483)	55 725 (75 552)	5° down	$1, 1, 1\frac{1}{2}, >8, >6, 1\frac{1}{2}$
11	25° with	30° up	0°	1440 (6405)	800 (3559)	175 (445)	187 (475)	1.7	4.47	21 000 (28 472)	12 466 (16 901)	35 760 (48 483)	55 725 (75 552)	10° down	$1\frac{1}{2}, \frac{1}{2}, >5, \infty, \infty$
12	25° with	30° up	0°	1440 (6405)	800 (3559)	175 (445)	187 (475)	1.7	8.94	21 000 (28 472)	12 466 (16 901)	35 760 (48 483)	111 450 (151 104)	10° down	$1, >4, \infty, 1\frac{1}{4}, 1\frac{1}{2}$
13	25° with	30° up	0°	1440 (6405)	800 (3559)	175 (445)	187 (475)	1.7	8.94	21 000 (28 472)	12 466 (16 901)	35 760 (48 483)	111 450 (151 104)	0°	$\infty, \frac{1}{2}, >4$
14	25° with	30° up	0°	1440 (6405)	1600 (7117)	175 (445)	187 (475)	1.7	4.47	21 000 (28 472)	24 933 (33 804)	35 760 (48 483)	111 450 (151 104)	0°	$\frac{1}{2}, \frac{1}{2}, \frac{1}{2}, \frac{1}{2}, \frac{1}{2}, \frac{1}{2}$
15	25° with	30° up	0°	1440 (6405)	1600 (7117)	175 (445)	140 (356)	1.7	4.47	21 000 (28 472)	18 667 (25 309)	35 760 (48 483)	82 442 (111 775)	0°	$\frac{1}{2}, \frac{1}{2}, \frac{1}{2}, \frac{1}{2}, \frac{1}{2}, \frac{1}{2}$
16	25° with	23° up	8° against	1440 (6405)	1600 (7117)	175 (445)	140 (356)	1.7	4.47	21 000 (28 472)	18 667 (25 309)	35 760 (48 483)	82 442 (111 775)	0°	$1, \frac{1}{2}, \frac{1}{2}, \frac{1}{2}, \frac{1}{2}, \frac{1}{2}$
17	25° with	0°	0°	1440 (6405)	1600 (7117)	175 (445)	140 (356)	1.7	4.47	21 000 (28 472)	18 667 (25 309)	35 760 (48 483)	82 442 (111 775)	0°	$1\frac{1}{2}, 2, 2, 1\frac{1}{2}, 1\frac{1}{2}, 1, 1\frac{1}{2}$
18	25° with	0°	0°	1440 (6405)	1600 (7117)	175 (445)	120 (305)	1.7	4.47	21 000 (28 472)	16 000 (21 693)	35 760 (48 483)	71 520 (96 967)	0°	$1, 1\frac{1}{2}, 2, 1\frac{1}{2}$

CHART 1.- SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL

[Recovery attempted by full rudder reversal unless otherwise noted. Recovery attempted from, and developed spin data presented for rudder-full-with spins.]

Airplane	Attitude Erect	Direction Right	Loading 9 (see table II) Normal Loading		
Slats	Flaps 0°		Center-of-gravity position 27.8% $\bar{c}$	Altitude 20,000 ft	Sponsons On

Model values converted to full scale   U-inner wing up   D-inner wing down



[a]Recovery attempted by neutralizing rudders.
[b]Recovered in a rolling dive.
[c]Oscillatory spin. Range or average values given.
[d]Recovery attempted by reversing rudders to $\frac{2}{3}$ against the spin.
[e]Recovered in an inverted dive.

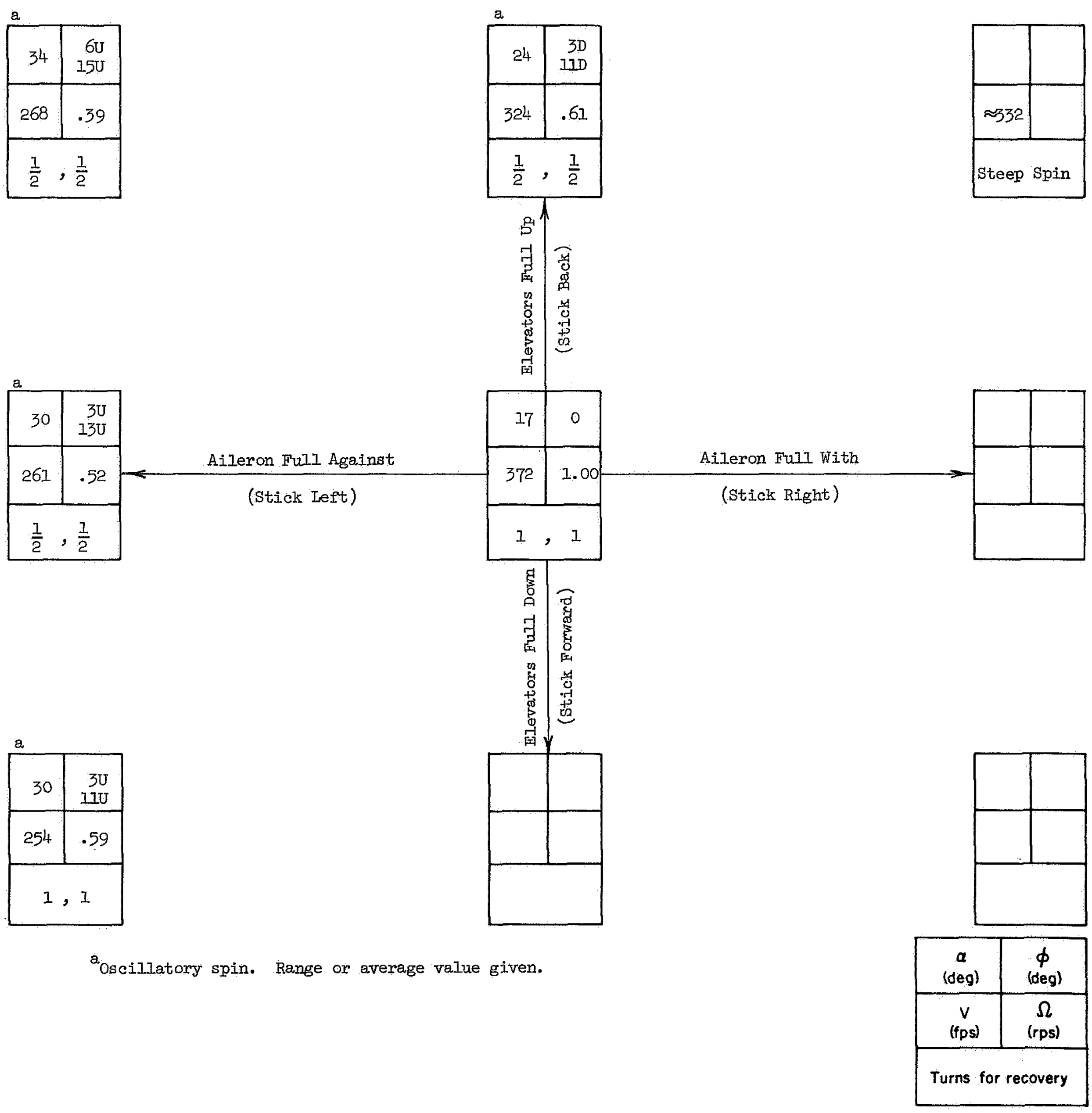
α (deg)	ϕ (deg)
V (fps)	Ω (rps)
Turns for recovery	

CHART 2.- SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL

[Recovery attempted by full rudder reversal unless otherwise noted. Recovery attempted from, and developed spin data presented for rudder-full-with spins.]

Airplane	Attitude Erect	Direction Right	Loading 8 (see table II) Most Forward C.G. Limit		
Slats	Flaps 0°		Center-of-gravity position 17.0% $\bar{c}$	Altitude 25,000 ft	Sponsons On

Model values converted to full scale   U–inner wing up   D–inner wing down



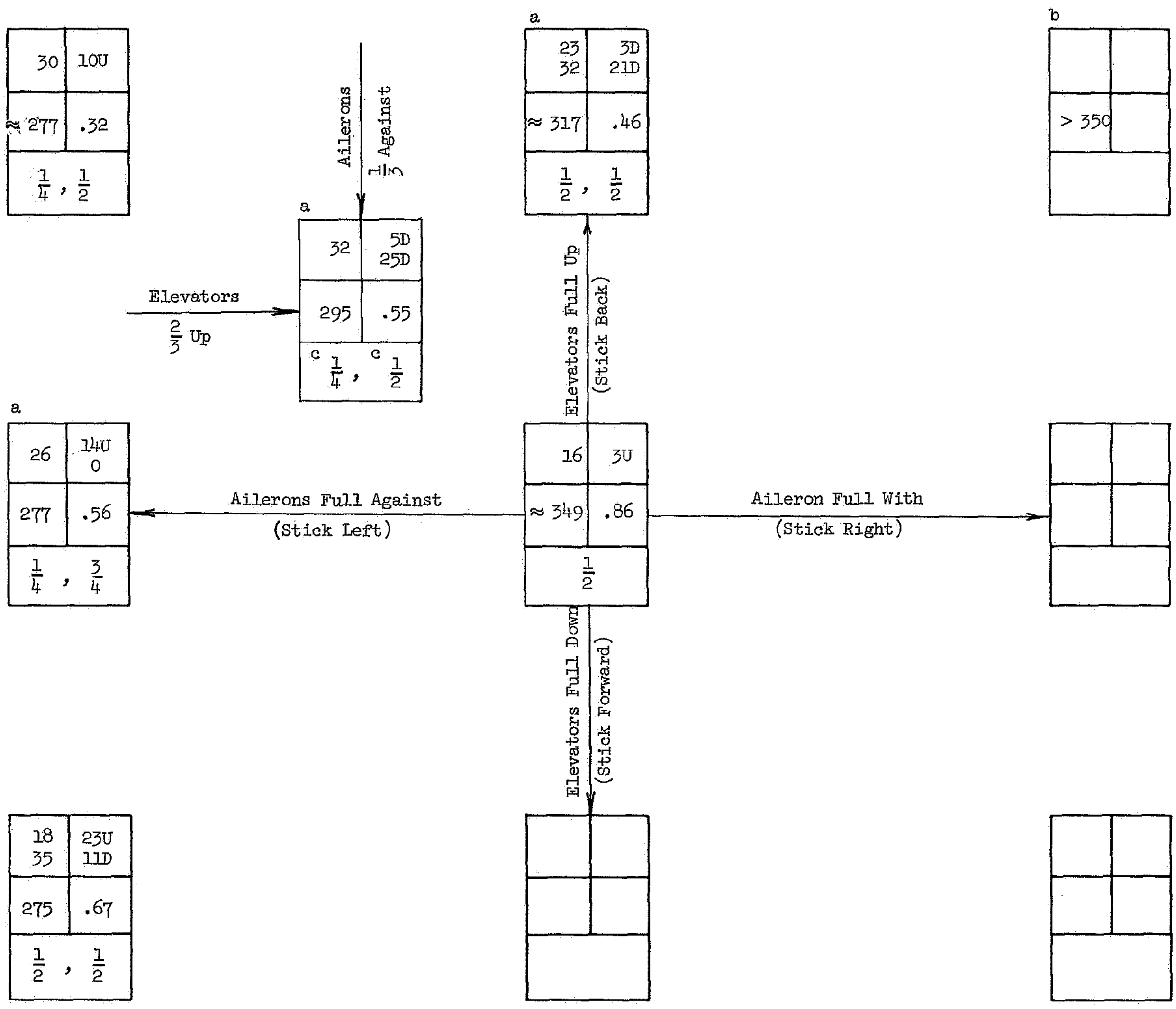
[a]Oscillatory spin. Range or average value given.

CHART 3.- SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL

[Recovery attempted by full rudder reversal unless otherwise noted. Recovery attempted from, and developed spin data presented for rudder-full-with spins.]

Airplane	Attitude Erect	Direction Right	Loading 6 (see table II) Normal Loading With Rearward C.G.		
Slots	Flaps 0°		Center-of-gravity position 30.3% $\bar{c}$	Altitude 20,000 ft	Sponsons On

Model values converted to full scale U–inner wing up D–inner wing down



[a]Oscillatory spin. Range or average values given.
[b]Wide radius spin.
[c]Recovery by reversing rudders to $\frac{2}{3}$ against the spin.

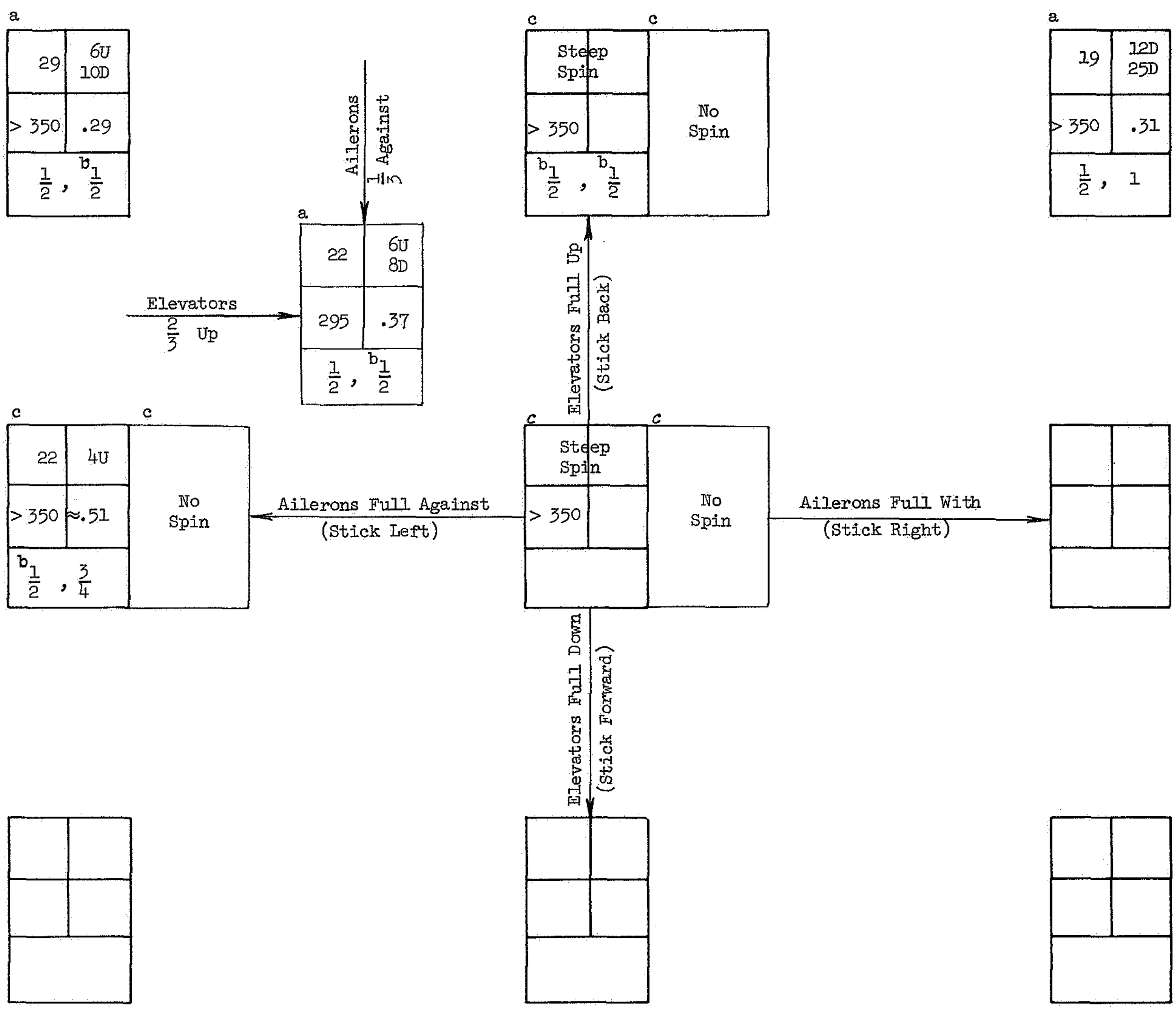
α (deg)	φ (deg)
V (fps)	Ω (rps)
Turns for recovery	

CHART 4.- SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL

[Recovery attempted by full rudder neutralization unless otherwise noted. Recovery attempted from, and developed spin data presented for rudder-full-with spins.]

Airplane	Attitude Erect	Direction Right	Loading 10 (see table II)		Normal Loading in Landing Configuration
Slats	Flaps 25° Down		Center-of-gravity position 27.5% $\bar{c}$	Altitude 20,000 ft	Sponsons On

Model values converted to full scale U–inner wing up D–inner wing down



α (deg)	ϕ (deg)
V (fps)	Ω (rps)
Turns for recovery	

[a]Oscillatory spin. Range or average values given.

[b]Visual estimate.

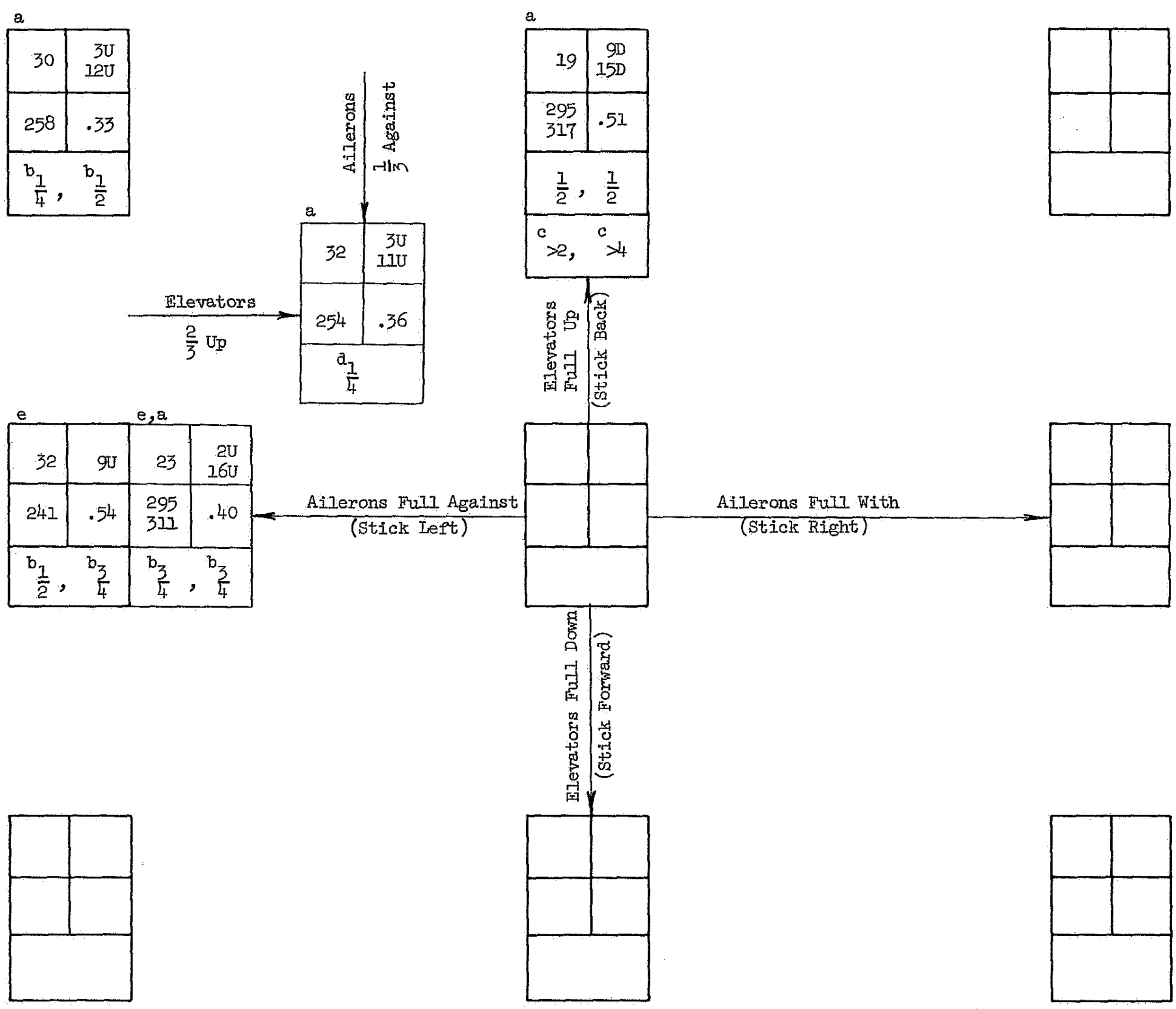
[c]Two conditions possible.

CHART 5.- SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL

[Recovery attempted by full rudder reversal unless otherwise noted. Recovery attempted from, and developed spin data presented for rudder-full-with spins.]

Airplane	Attitude Erect	Direction Right	Loading 9 (see table II) Normal Loading		
Slats	Flaps 0°		Center-of-gravity position 27.8% $\bar{c}$	Altitude 20,000 ft	Sponsons Off

Model values converted to full scale   U–inner wing up   D–inner wing down



[a]Oscillatory spin. Range or average values given.

[b]May spin in opposite direction on recovery.

[c]Recovery attempted by neutralizing rudder.

[d]Recovery by reversing rudder to $\frac{2}{3}$ against the spin.

[e]Two conditions possible.

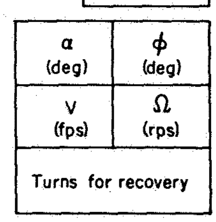
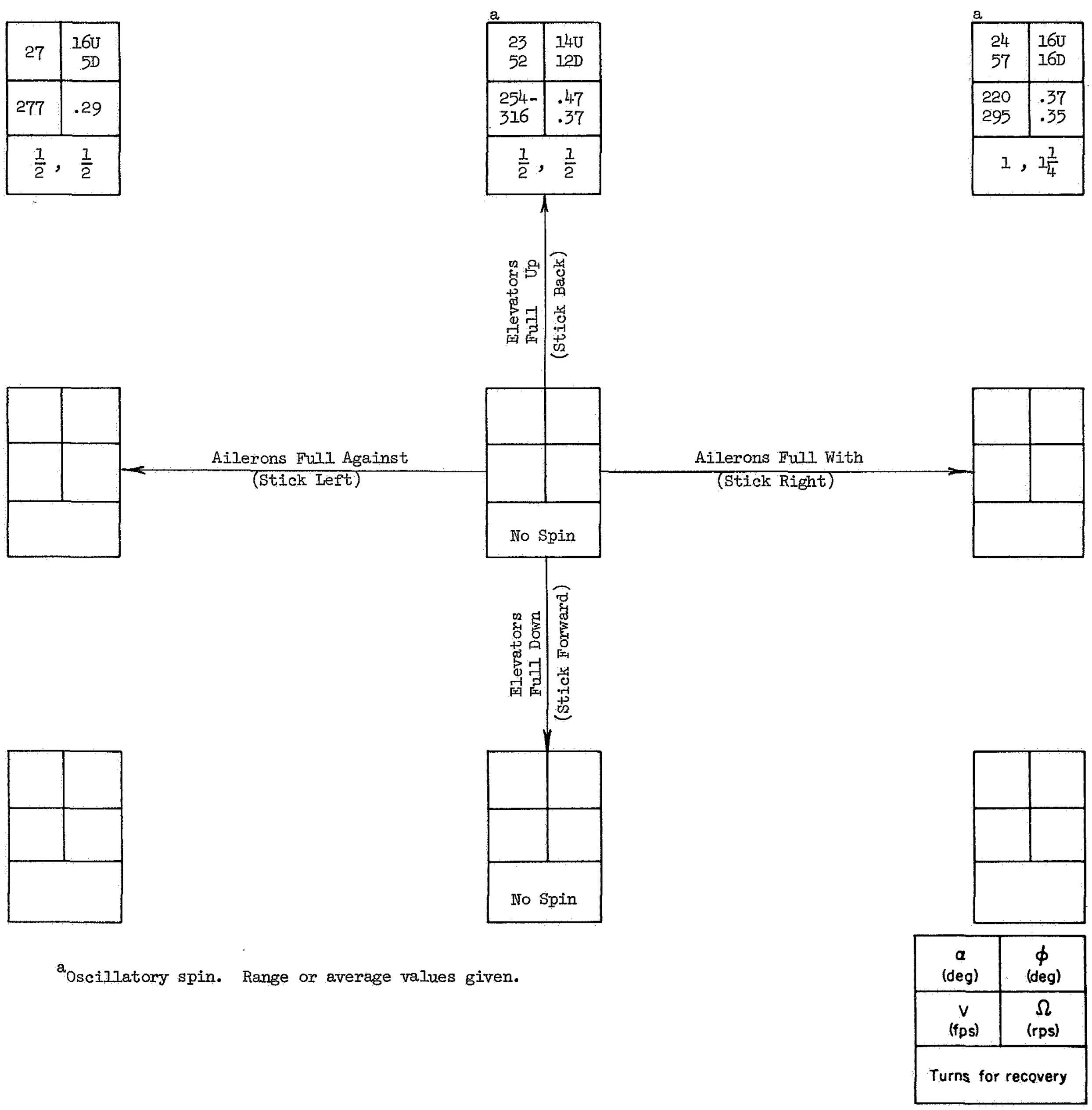


CHART 6.- SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL

[Recovery attempted by full rudder reversal unless otherwise noted. Recovery attempted from, and developed spin data presented for rudder-full-with spins.]

Airplane	Attitude	Direction	Loading 11 (see table II) Normal Loading With Wing Tip Sidewinder Missiles On		
	Erect	Right			
Slats	Flaps		Center-of-gravity position	Altitude	Sponsons On
	0°		29.9% $\bar{c}$	20,000 ft	

Model values converted to full scale U–inner wing up D–inner wing down



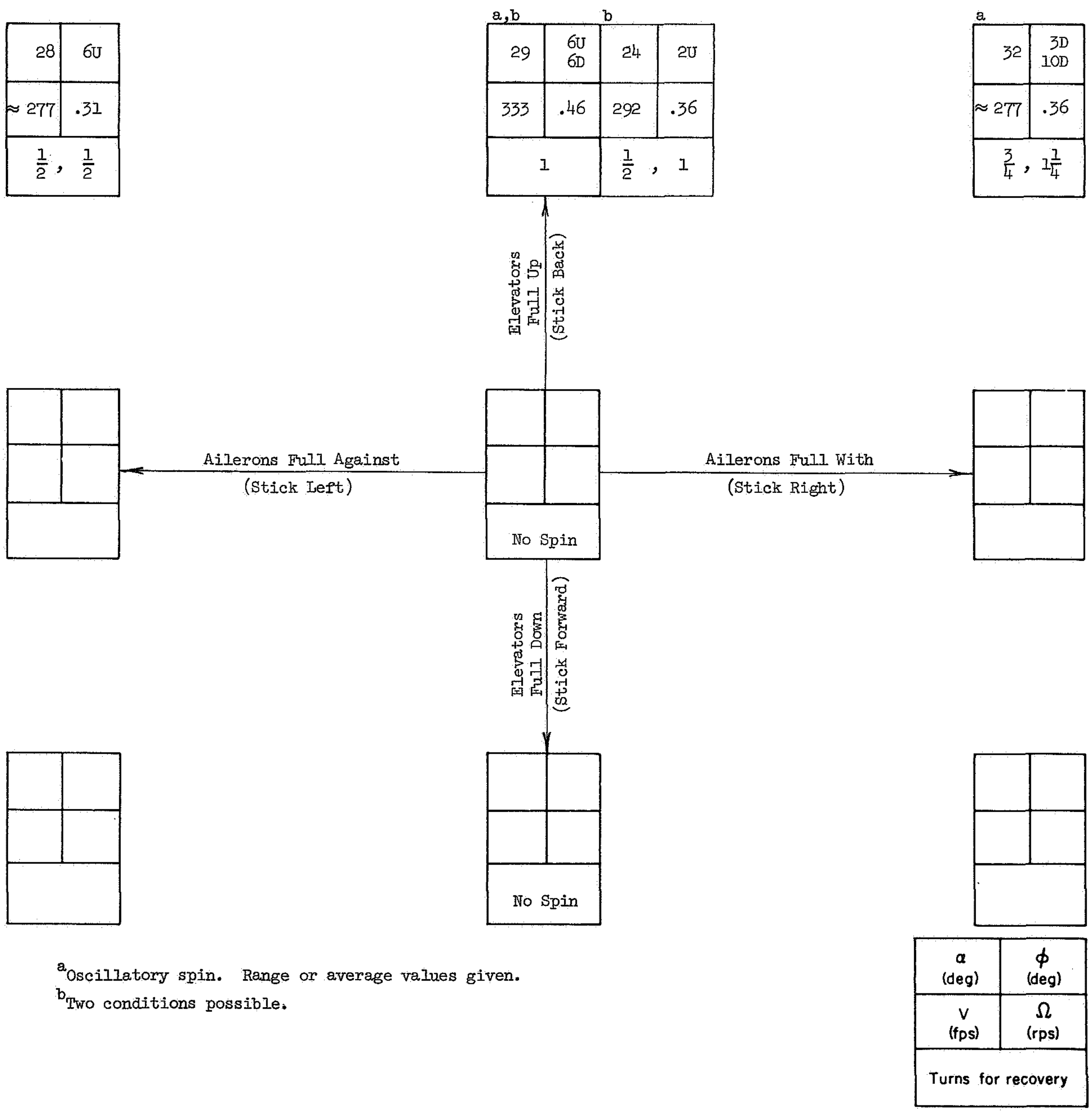
[a]Oscillatory spin. Range or average values given.

CHART 7.- SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL

[Recovery attempted by full rudder reversal unless otherwise noted. Recovery attempted from, and developed spin data presented for rudder-full-with spins.]

Airplane	Attitude	Direction	Loading 12 (see table II)		Normal Loading With Wing Tip Sidewinder Missiles On
	Erect	Right			
Slats	Flaps 0°		Center-of-gravity position 30.7% $\bar{c}$	Altitude 20,000 ft	Sponsons On

Model values converted to full scale — U-inner wing up — D-inner wing down



[a]Oscillatory spin. Range or average values given.

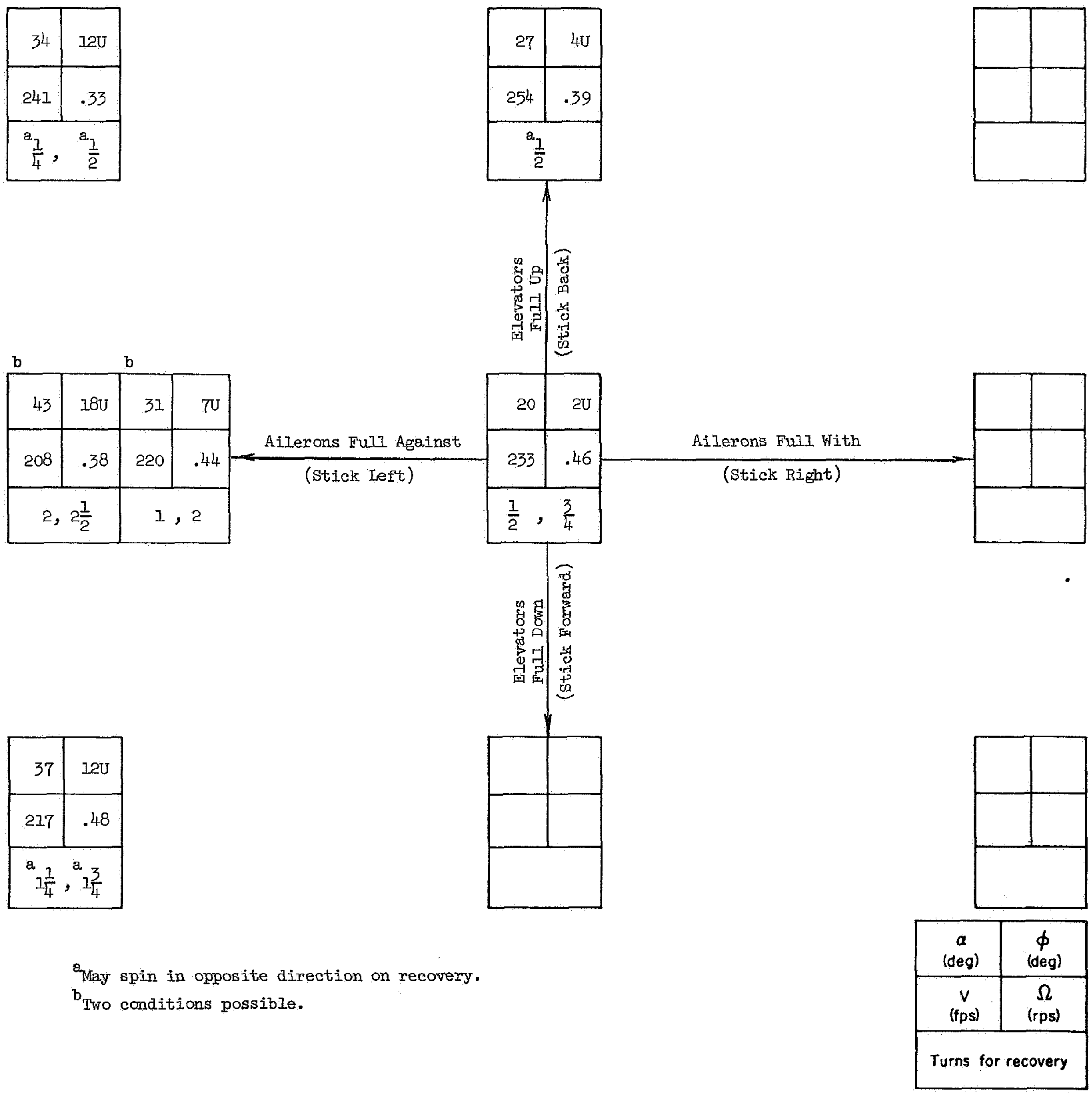
[b]Two conditions possible.

CHART 8.- SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL

[Recovery attempted by full rudder reversal unless otherwise noted. Recovery attempted from, and developed spin data presented for rudder-full-with spins.]

Airplane	Attitude	Direction	Loading 13 (see table II)		
	Erect	Right	Normal Loading With Four External Rocket Pods On		
Slats	Flaps 0°		Center-of-gravity position 30.1% $\bar{c}$	Altitude 20,000 ft	Sponsons On

Model values converted to full scale   U–inner wing up   D–inner wing down



[a]May spin in opposite direction on recovery.

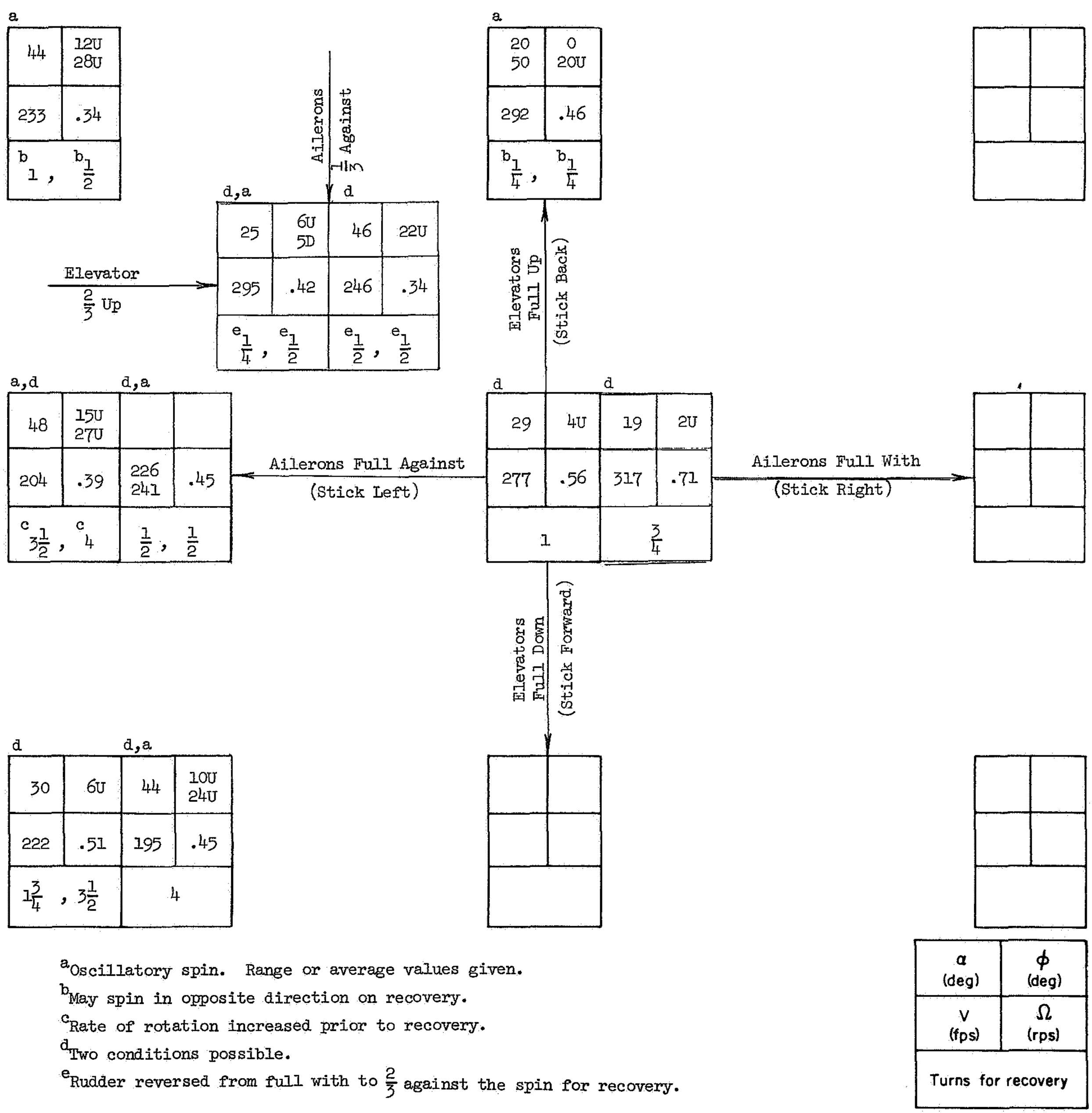
[b]Two conditions possible.

CHART 9.- SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL

[Recovery attempted by full rudder reversal unless otherwise noted. Recovery attempted from, and developed spin data presented for rudder-full-with spins.]

Airplane	Attitude	Direction	Loading 13 (see table II)		Normal Loading With Center Gun Pod On
	Erect	Right			
Slats	Flaps		Center-of-gravity position	Altitude	Sponsons On
	0°		30.1% $\bar{c}$	20,000 ft	

Model values converted to full scale U–inner wing up D–inner wing down



[a]Oscillatory spin. Range or average values given.

[b]May spin in opposite direction on recovery.

[c]Rate of rotation increased prior to recovery.

[d]Two conditions possible.

[e]Rudder reversed from full with to $\frac{2}{3}$ against the spin for recovery.

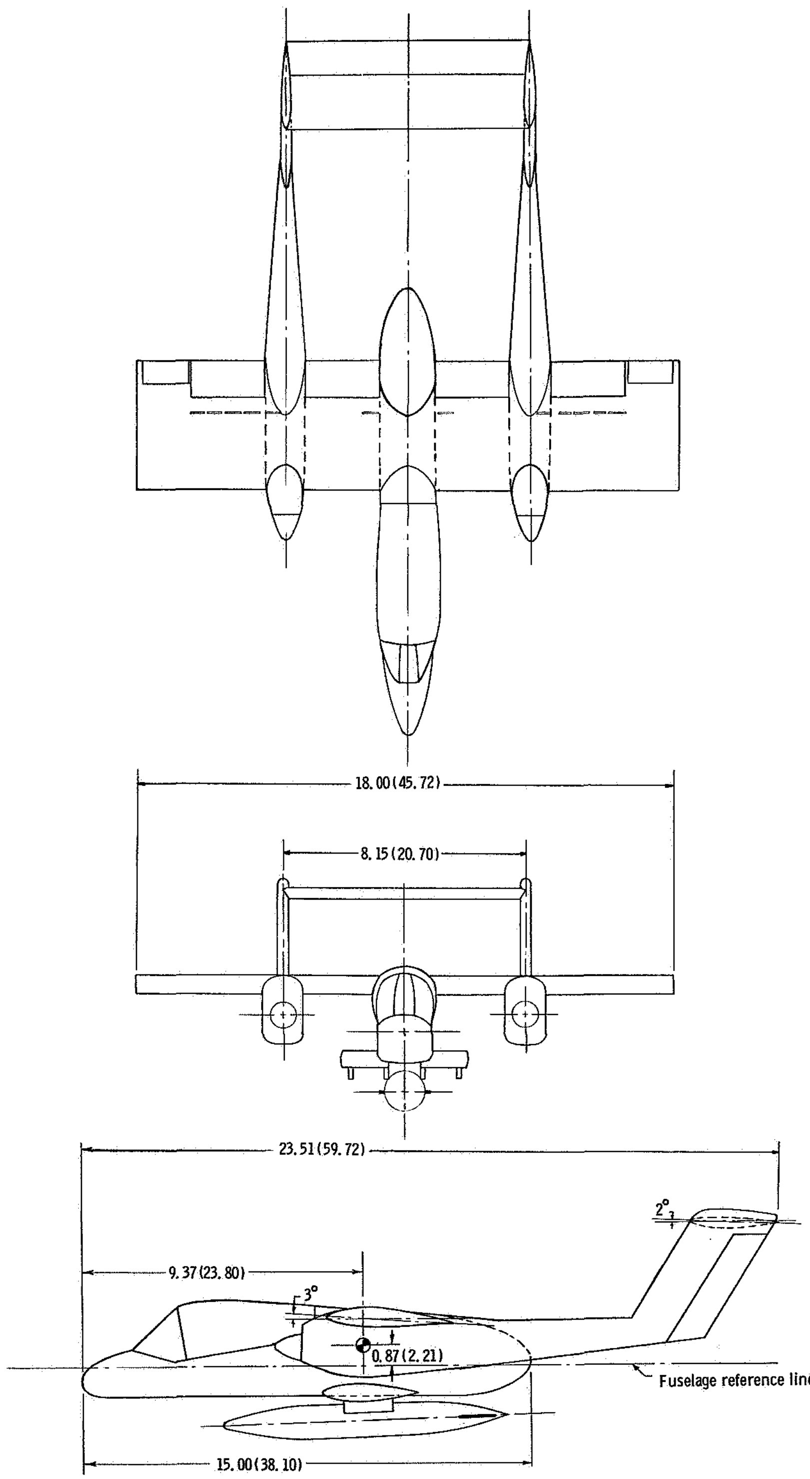
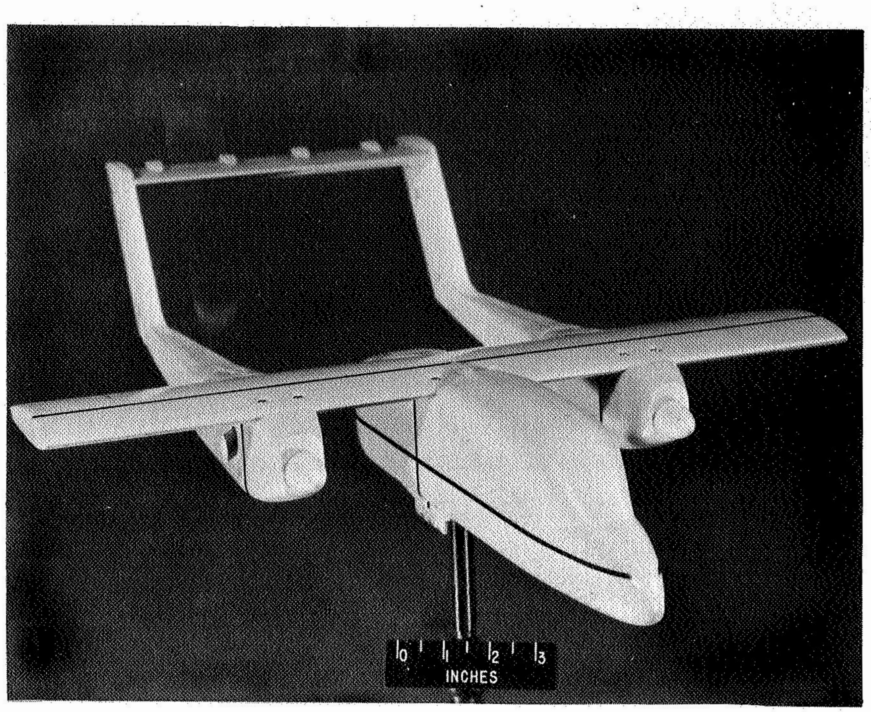
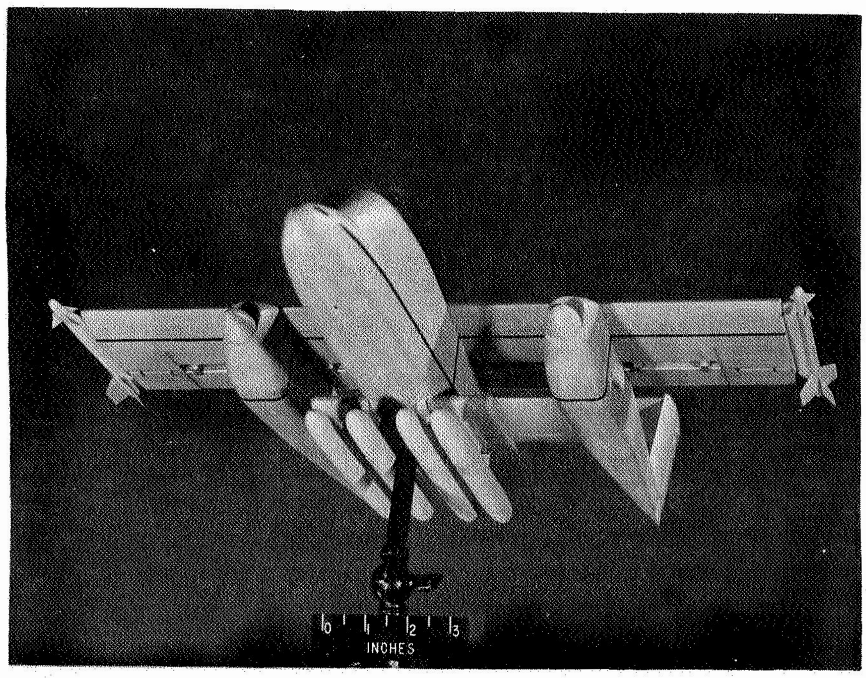


Figure 1.- Three-view drawing of the 1/20-scale model. Center-of-gravity position shown is 27.8 percent $\bar{c}$. All dimensions are in inches, parenthetically in centimeters.



(a) Clean model. L-65-4391



(b) Rocket pods and sidewinder missiles on. L-65-4394

Figure 2.- The 1/20-scale model as tested in the Langley 20-foot spin tunnel.

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